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# TEMPERATURE AND RELATIVE HUMIDITY IN THE ATMOSPHERE OVER LOWER EGYPT

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# TEMPERATURE AND RELATIVE HUMIDITY IN THE ATMOSPHERE OVER LOWER EGYPT

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**General.**—The purpose of this paper is to present tables of mean values of temperature and relative humidity in the atmosphere compiled from the early morning observations of temperature in the upper air made during the period 1922 to 1930 at inland stations in Lower Egypt.

Ascents were made from Helwan (29° 52′ N., 31° 20′ E., 41 m.), Heliopolis (30° 5′ N., 31° 22′ E., 51 m.) and Ismailia (30° 36′ N., 32° 14′ E., 14 m.), and when ascents were carried out at more than one station on the same day the readings from that which reached the greatest altitude have been considered. The bulk of the observations were made at Helwan between October, 1923 and May, 1925, and to a lesser extent at Ismailia between March and September, 1922, and at Heliopolis between July and September, 1923. Some of these ascents have been discussed by Newnham (1)* and by Peters (2) who have considered, amongst other things, the weather and upper winds associated with individual ascents.

The ascents were made by aeroplane, and temperature readings were obtained from either a strut psychrometer or a strut thermometer mounted on an outer wing strut and clear of the slip-stream. Readings were made in degrees Fahrenheit and have been converted to degrees Centigrade. The commencement of the early morning ascent was between approximately 0700 and 0800 local time which in Egypt is two hours fast on G.M.T. In making the observations the system adopted was to report temperatures corresponding with specified pressures at intervals of 50 millibars although in some ascents readings were taken at every 1,000 feet altimeter height from the surface. The time taken to reach a height corresponding to a pressure of 650 millibars was about 60 minutes and the readings obtained during the ascent have been used for compiling the present tables.

**Temperatures in the Upper Air.**—(*a*) *Monthly Mean Values.*—The mean values of temperature at successive heights of 0·5 Km. above sea level for each month are given in Table I. The outstanding feature of the figures is the gradual increase in temperature from January to August followed by a rapid decrease during the last quarter of the year. The temperatures for August and January indicate that there is very little retardation between the occurrence of maximum and minimum monthly mean temperatures of the air up to at least 4·0 Km. over Lower Egypt. The modification of the monthly increase in temperature between April and May may be associated with the fact that April is the month of maximum frequency of occurrence of short and very pronounced periods of high temperature in the lowest layers (3). The deviation of the values from the normals for south-east England (4) are, as is to be expected, all positive (Table II).

* The numbers in brackets refer to the bibliography on p. 12.

## TABLE I.—MONTHLY MEAN TEMPERATURE IN THE EARLY MORNING (0700–0800) FOR DIFFERENT HEIGHTS ABOVE LOWER EGYPT (HELWAN, HELIOPOLIS, ISMAILIA) TOGETHER WITH THE NUMBER OF OBSERVATIONS AT EACH HEIGHT

| Height above M.S.L. | Jan. | | Feb. | | Mar. | | Apr. | | May | | June | | July | | Aug. | | Sept. | | Oct. | | Nov. | | Dec. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Temp-erature | No. of Obs. | Temp-erature | No. of Obs. | Temp-erature | No. of Obs. | Temp-erature | No. of Obs. | Temp-erature | No. of Obs. | Temp-erature | No. of Obs. | Temp-erature | No. of Obs. | Temp-erature | No. of Obs. | Temp-erature | No. of Obs. | Temp-erature | No. of Obs. | Temp-erature | No. of Obs. | Temp-erature | No of Obs. |
| Km. | °C. | | °C. | | °C. | | °C. | | °C. | | °C. | | °C. | | °C. | | °C. | | °C. | | °C. | | °C. | |
| 6·0 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | (−2·8) | 2 | .. | .. | .. | .. | .. | .. | .. | .. |
| 5·5 | .. | .. | .. | .. | .. | .. | .. | .. | (−11·1) | 1 | .. | .. | (0·6) | 1 | (−0·6) | 4 | .. | .. | .. | .. | (−7·2) | 1 | (−20·0) | 1 |
| 5·0 | (−10·6) | 1 | .. | .. | (−8·9) | 5 | (−7·2) | 10 | (− 6·7) | 10 | (−1·7) | 12 | (2·8) | 7 | 1·1 | 25 | (1·1) | 9 | (−9·4) | 10 | (−6·1) | 13 | (−10·6) | 4 |
| 4·5 | (− 8·3) | 10 | (−9·4) | 3 | (−6·1) | 8 | (−2·2) | 14 | (− 3·9) | 12 | (1·7) | 14 | (6·1) | 8 | 4·4 | 34 | (3·3) | 13 | −3·9 | 23 | −3·9 | 20 | − 6·7 | 15 |
| 4·0 | − 7·2 | 30 | −6·1 | 20 | (−2·8) | 18 | 0·6 | 29 | − 0·6 | 37 | 3·9 | 34 | 6·7 | 28 | 7·2 | 41 | 5·6 | 22 | −0·6 | 31 | −0·6 | 24 | − 3·9 | 21 |
| 3·5 | − 5·0 | 42 | −2·8 | 30 | 0·0 | 32 | 3·3 | 46 | 2·8 | 52 | 7·2 | 48 | 9·4 | 41 | 10·0 | 53 | 8·9 | 34 | 3·3 | 48 | 1·7 | 37 | − 1·1 | 36 |
| 3·0 | − 2·2 | 56 | −0·6 | 44 | 3·9 | 55 | 6·7 | 67 | 7·2 | 74 | 10·6 | 54 | 12·2 | 41 | 12·8 | 63 | 12·2 | 49 | 7·2 | 67 | 5·0 | 48 | 1·7 | 60 |
| 2·5 | − 0·6 | 58 | 2·2 | 51 | 6·7 | 61 | 9·4 | 78 | 10·0 | 88 | 13·9 | 60 | 14·4 | 47 | 15·6 | 67 | 14·4 | 57 | 10·0 | 72 | 7·2 | 50 | 3·3 | 61 |
| 2·0 | 1·7 | 67 | 4·4 | 55 | 8·9 | 61 | 11·7 | 80 | 13·3 | 88 | 16·7 | 60 | 17·2 | 68 | 17·8 | 81 | 17·2 | 65 | 12·8 | 72 | 9·4 | 50 | 6·5 | 63 |
| 1·5 | 3·9 | 72 | 7·2 | 55 | 11·1 | 61 | 14·4 | 84 | 16·7 | 89 | 20·0 | 62 | 20·0 | 70 | 20·6 | 88 | 19·4 | 69 | 15·0 | 73 | 12·2 | 50 | 8·3 | 63 |
| 1·0 | 6·7 | 77 | 9·4 | 57 | 12·8 | 62 | 16·1 | 86 | 19·4 | 89 | 21·7 | 62 | 21·7 | 70 | 22·2 | 89 | 21·1 | 69 | 17·8 | 74 | 14·4 | 51 | 10·6 | 63 |
| 0·5 | 9·4 | 77 | 11·7 | 57 | 14·4 | 62 | 17·2 | 86 | 21·1 | 89 | 22·8 | 62 | 22·2 | 70 | 22·8 | 89 | 22·2 | 69 | 20·0 | 74 | 16·1 | 51 | 12·8 | 63 |
| Surface | 8·3 | 77 | 9·4 | 57 | 15·0 | 62 | 18·3 | 86 | 22·2 | 89 | 25·6 | 62 | 24·4 | 70 | 24·4 | 89 | 23·9 | 69 | 20·0 | 74 | 17·8 | 51 | 11·7 | 63 |

*Note.*—Values, the mean of less than 20 observations, are enclosed in brackets.

## TABLE II—DEVIATIONS OF MEAN TEMPERATURES AT 0700–0800 OVER LOWER EGYPT FROM THOSE OVER SOUTH-EAST ENGLAND

| Height | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Km. | °C. | °C. | °C. | °C. | °C. | °C. | °C. | °C. | °C. | °C. | °C. | °C. |
| 5 | (12·2) | .. | (13·9) | (13·9) | (10·6) | (12·2) | (15·0) | (12·2) | (13·3) | (5·6) | (11·7) | (10·6) |
| 4 | 8·9 | 11·1 | (13·3) | 14·4 | 10·6 | 11·7 | 12·8 | 12·2 | 11·7 | 8·3 | 11·7 | 11·1 |
| 3 | 7·8 | 10·6 | 13·9 | 14·4 | 12·2 | 12·8 | 12·2 | 11·7 | 12·2 | 10·0 | 11·1 | 10·6 |
| 2 | 7·8 | 11·7 | 15·0 | 14·4 | 13·3 | 13·9 | 12·2 | 11·7 | 12·2 | 10·6 | 10·6 | 9·3 |
| 1 | 8·9 | 11·7 | 12·8 | 13·3 | 13·3 | 12·8 | 11·7 | 12·2 | 13·3 | 11·7 | 12·2 | 11·7 |
| Mean 12·0 | 9·1 | 11·3 | 13·8 | 14·1 | 12·0 | 12·7 | 12·8 | 12·0 | 12·5 | 9·2 | 11·4 | 10·7 |

*Note.*—For values enclosed in brackets there were less than 20 observations available for Egypt.

(*b*) *Lapse Rate.*—The monthly mean lapse rates are given in Table III and the values exhibit no definite seasonal variation. Comparing the values from 2 Km. upwards with those calculated by Gold (5) for England the lapse rate up to 5 Km. over Egypt is smaller during the months November to February and in July and greater during May. During the remaining months the lapse rate is approximately the same over the two regions considered at all levels although during January, June, August and October the difference in lapse rate fluctuates irregularly from level to level. A comparison of the values below 2 Km. is not warranted as the lapse rates observed over Egypt will be phenomena peculiar to the early morning.

TABLE III—MONTHLY MEAN VALUES OF THE LAPSE RATE IN THE EARLY MORNING, 0700–0800 IN °C./KM. FOR EACH KM. AND THE MEAN LAPSE RATE FROM 1 TO 5 KM.

| Height above M.S.L. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Km. | °C./Km. | °C./Km. | °C./Km. | °C./Km. | °C./Km. | °C./Km. | °C./Km. | °C./Km. | °C./Km. | °C./Km. | °C./Km. | °C./Km. |
| 4–5 | (4·6)† | (5·6)* | (6·7)* | (6·6)* | (7·1) | (5·7)* | (5·3) | 5·9* | (5·0)* | 7·1* | 6·4* | (5·1)* |
| 3–4 | 5·6* | 5·6* | 6·1* | 6·8* | 6·3* | 6·9* | 5·3* | 6·2* | 6·3* | 6·8* | 5·5* | 5·7* |
| 2–3 | 3·9 | 4·7* | 5·1 | 5·7 | 6·3 | 5·9 | 5·6 | 5·4 | 4·8 | 5·6 | 4·4 | 4·3 |
| 1–2 | 5·2 | 4·9 | 4·0 | 4·4 | 5·9 | 4·8 | 4·4 | 4·5 | 4·1 | 5·1 | 5·0 | 4·8 |
| 0–1 | 1·4 | 0·8 | 2·0 | 2·4 | 2·7 | 3·8 | 2·8 | 3·2 | 2·7 | 3·1 | 3·1 | 1·1 |
| 1–5 | (4·3) | (4·9)‡ | (6·1) | (5·8) | (6·6) | (5·4) | (4·6) | 5·3 | (5·1) | (7·1) | (5·6) | (5·9) |

*Notes.*—Values enclosed in brackets are means of less than 20 observations.

† Computed from the decrease in temperature over the lower half kilometre of this layer.

* Readings over the lower half kilometre of this layer taken into consideration when computing the means.

‡ Computed from the decrease in temperature between 1 and 4·5 Km.

In the afternoon, about the time of maximum temperature at the surface, much larger lapse rates occur in the lowest layers of the atmosphere and the results of a few ascents commenced between 1400 and 1430 are given in Table IV. In the afternoon the mean lapse rate up to 1 Km. equals or exceeds the adiabatic for unsaturated air during the first eight months of the year and is only slightly less during the remaining months. The highest values observed indicate that a lapse rate exceeding the adiabatic for unsaturated air may be expected up to 1 Km. at any time of the year and up to 2 Km. during May and June. The figures also suggest that the height to which diurnal variation of the lapse rate extends in spring and summer is between 3 and 4 Km. but less than 3 Km. in winter.

TABLE IV.—MONTHLY MEAN AND MAXIMUM VALUES OF THE LAPSE RATE IN THE AFTERNOON (1400) IN °C./KM. FOR EACH KILOMETRE

| Height above M.S.L. | Jan. 6 | Feb. 7 | Mar. 7 | Apr. 5 | May 7 | June 4 | July 5 | Aug. 4 | Sept. 5 | Oct. 4 | Nov. 7 | Dec. 7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Km. | Monthly Mean Lapse Rate | | | | | | | | | | | |
| 3–4 | 3·6* | 5·6* | 5·3* | 7·3† | 6·4* | 8·3* | 4·2* | 5·3* | 8·3* | 6·1* | 5·6 | 3·7† |
| 2–3 | 3·8 | 6·4 | 5·6 | 7·7 | 5·8 | 6·7 | 6·9 | 4·6 | 5·6 | 6·1 | 6·2 | 4·2 |
| 1–2 | 4·9 | 6·5 | 5·2 | 5·7 | 8·3 | 8·3 | 7·3 | 6·8 | 7·2 | 5·8 | 6·5 | 7·0 |
| 0–1 | 11·5 | 10·2 | 10·6 | 9·9 | 10·9 | 10·9 | 10·3 | 10·2 | 8·8 | 9·6 | 9·4 | 8·8 |
| | Maximum Lapse Rate | | | | | | | | | | | |
| 3–4 | 5·6 | 7·8* | 8·9* | 8·9* | 8·9* | 10·0* | 5·6* | 6·7* | 10·0* | 6·7* | 6·7 | 6·7* |
| 2–3 | 7·2 | 9·4 | 9·4 | 9·4 | 7·8 | 9·4 | 9·4 | 6·1 | 6·1 | 6·7 | 7·8 | 6·7 |
| 1–2 | 7·8 | 8·9 | 8·9 | 8·9 | 10·0 | 14·4 | 9·4 | 8·9 | 8·9 | 8·3 | 9·4 | 8·9 |
| 0–1 | 14·4 | 12·2 | 12·8 | 11·7 | 13·9 | 13·9 | 11·1 | 11·1 | 10·0 | 10·6 | 12·2 | 12·8 |

*Notes.*—The figures under the month represent the number of ascents available.

* Extrapolated from readings over the lower half kilometre of the layer concerned.

† Extrapolated values from readings over the lower half kilometre of the layer concerned taken into consideration when computing these figures.

(*c*) *Extreme Values of Temperature at each Height.*—The highest and lowest values of temperature recorded at various heights were extracted and the resulting figures show that the lowest temperatures up to 3 Km. are observed in January and above 3 Km. in February, while the highest temperatures occurred during August, although at 1 Km. and below comparable temperatures were also reached during the four months April to July. The smallest range of temperature occurred at all levels in September when it increased from 11° C. at the surface to 15° C. at 1 Km., decreased suddenly to about 10° C. at 1·5 Km. and then showed little change up to 3 Km. when it again decreased to 5° C. for the remaining levels. Up to 3 Km. the greatest range occurred in April with a value of about 25° C. at each level while between 3 and 4 Km. it occurred in February, the range in this case being 16° C. at each level.

**Relative Humidity and Vapour Pressure in the Upper Air.**—(*a*) *Monthly Mean Values of Relative Humidity.*—Monthly mean values of relative humidity at specified heights above sea level are given in Table V. All observations were scrutinised in order to detect cases either of rapid evaporation leading to the water container being emptied before the completion of a flight or of the non-effectiveness of the wet bulb at temperatures below freezing point owing to the complete evaporation of the coating of ice on the muslin. All doubtful cases have been rejected with the result that the mean

TABLE V—MONTHLY MEAN PERCENTAGE RELATIVE HUMIDITY AT 0700–0800 FOR DIFFERENT HEIGHTS ABOVE LOWER EGYPT TOGETHER WITH THE NUMBER OF OBSERVATIONS (N) AT EACH HEIGHT

| Height above M.S.L. | Jan. | | Feb. | | Mar. | | Apr. | | May | | June | | July | | Aug. | | Sept. | | Oct. | | Nov. | | Dec. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Km. | % | N | % | N | % | N | % | N | % | N | % | N | % | N | % | N | % | N | % | N | % | N | % | N |
| 5·0 | .. | | .. | | .. | | (53) | 2 | .. | | .. | | .. | | .. | | .. | | .. | | .. | | .. | |
| 4·5 | .. | | .. | | .. | | (52) | 2 | .. | | .. | | .. | | 28 | 27 | (42) | 11 | .. | | (71) | 10 | (83) | 5 |
| 4·0 | .. | | (56) | 16 | (54) | 7 | (35) | 9 | (37) | 8 | (32) | 7 | 33 | 25 | 24 | 33 | (39) | 18 | (59) | 6 | 68 | 20 | (72) | 10 |
| 3·5 | (65) | 18 | 53 | 24 | 55 | 22 | 32 | 23 | 39 | 26 | 25 | 37 | 31 | 38 | 29 | 45 | 39 | 34 | 50 | 40 | 57 | 36 | 70 | 27 |
| 3·0 | 67 | 42 | 53 | 36 | 49 | 46 | 28 | 45 | 37 | 52 | 26 | 46 | 33 | 38 | 31 | 55 | 40 | 51 | 47 | 63 | 50 | 48 | 58 | 52 |
| 2·5 | 64 | 46 | 55 | 46 | 43 | 53 | 27 | 57 | 37 | 66 | 25 | 52 | 35 | 44 | 31 | 59 | 40 | 51 | 47 | 70 | 51 | 50 | 55 | 56 |
| 2·0 | 61 | 48 | 58 | 49 | 44 | 54 | 27 | 57 | 37 | 66 | 29 | 52 | 36 | 44 | 31 | 59 | 42 | 52 | 49 | 70 | 56 | 50 | 58 | 58 |
| 1·5 | 66 | 49 | 61 | 50 | 46 | 55 | 29 | 57 | 35 | 66 | 32 | 53 | 36 | 44 | 40 | 59 | 44 | 53 | 55 | 71 | 64 | 50 | 64 | 59 |
| 1·0 | 77 | 49 | 67 | 53 | 56 | 57 | 38 | 58 | 41 | 67 | 38 | 54 | 45 | 44 | 48 | 60 | 51 | 53 | 57 | 71 | 67 | 50 | 68 | 59 |
| 0·5 | 76 | 50 | 75 | 53 | 64 | 58 | 51 | 58 | 48 | 68 | 54 | 54 | 62 | 44 | 68 | 60 | 65 | 53 | 69 | 71 | 75 | 50 | 70 | 59 |
| Surface | 83 | 50 | 76 | 53 | 72 | 58 | 66 | 57 | 63 | 68 | 63 | 56 | 76 | 44 | 74 | 60 | 81 | 53 | 78 | 71 | 81 | 50 | 79 | 59 |

*Note.*—The region above the thick line is that in which the mean temperature is below 0°C.
Values, the mean of less than 20 observations, are enclosed in brackets.

values at the upper levels have been computed from only a few readings. Individual values of relative humidity were computed according to the formula—

$$e'' = e' - 0{\cdot}666\ (t - t')\ B/1{,}000$$

where $e''$ is the vapour pressure corresponding with the given readings of the dry and wet bulb, $e'$ is the saturation vapour pressure at the temperature of the wet bulb, $t$ and $t'$ are respectively the temperatures of the dry and wet bulb and $B$ is the pressure at the height concerned.

(*b*) *Monthly Mean Values of Vapour Pressure.*—The mean values of vapour pressure (Table VI) were computed from the mean values of temperature quoted in Table I and the mean values of relative humidity given in Table V. Very little error is involved in doing this instead of using the individual values as all the readings used were taken from ascents commenced between 0700 and 0800. The hygrometric tables in use in the Meteorological Office, London (M.O. 265), were used in the determination of the vapour pressure. It is interesting to note that the normal vapour pressure over Lower Egypt is greater than that over England (6) at all levels ; this is most marked below 1 Km. where the amount of water vapour present during summer is approximately double that occurring over England.

TABLE VI—MONTHLY MEAN VALUES OF THE VAPOUR PRESSURE AT 0700–0800 AT DIFFERENT HEIGHTS.

| Height above M.S.L. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Km. | mb. | mb. | mb. | mb. | mb. | mb. | mb. | mb. | mb. | mb. | mb. | mb. |
| 5·0 | .. | .. | .. | 1·7 | .. | .. | .. | .. | .. | .. | .. | .. |
| 4·5 | .. | .. | .. | 2·6 | .. | .. | .. | 2·4 | 3·3 | .. | 3·1 | 2·9 |
| 4·0 | .. | 2·1 | 2·6 | 2·3 | 2·1 | 2·6 | 3·2 | 2·4 | 3·5 | 3·5 | 4·0 | 3·2 |
| 3·5 | 2·7 | 2·5 | 3·3 | 2·5 | 2·9 | 2·5 | 3·9 | 3·5 | 4·4 | 3·9 | 3·9 | 3·9 |
| 3·0 | 3·5 | 3·1 | 3·9 | 2·7 | 3·8 | 3·3 | 4·7 | 4·5 | 5·7 | 4·8 | 4·3 | 4·0 |
| 2·5 | 3·7 | 3·7 | 4·2 | 3·2 | 4·5 | 3·9 | 5·7 | 5·5 | 6·6 | 5·8 | 5·4 | 4·3 |
| 2·0 | 4·2 | 4·9 | 5·0 | 3·7 | 5·7 | 5·5 | 7·1 | 6·3 | 8·3 | 7·3 | 6·6 | 5·3 |
| 1·5 | 5·3 | 6·2 | 6·1 | 4·7 | 6·7 | 7·5 | 8·4 | 9·7 | 9·9 | 9·3 | 9·1 | 7·0 |
| 1·0 | 7·5 | 7·9 | 8·3 | 7·0 | 9·3 | 9·9 | 11·7 | 12·9 | 12·7 | 11·6 | 11·1 | 8·7 |
| 0·5 | 9·0 | 10·3 | 10·5 | 10·0 | 12·0 | 15·0 | 16·6 | 19·9 | 17·5 | 15·1 | 13·7 | 10·3 |
| Surface | 9·1 | 9·0 | 12·3 | 13·9 | 16·9 | 20·7 | 23·3 | 22·7 | 24·0 | 18·3 | 16·5 | 10·9 |

(*c*) *Maximum and Minimum Values of Relative Humidity.*—Maximum and minimum values of relative humidity were extracted for each height and the results show that the atmosphere on occasions is almost free of water vapour. In order to exhibit the extreme dryness of the air at such times the vapour pressure corresponding with the minimum values of relative humidity have

been computed (Table VII). For temperatures below the freezing point the values exhibit a fairly rapid rise but this increase may be associated with the method of observation. Maximum values of relative humidity show that during the months October to March, 90 per cent has been exceeded at all levels and that cases of almost complete saturation were of frequent occurrence below 2 Km. in cloud or fog. The maxima above 1·5 Km. were lower in the remaining months and were no higher than about 60 per cent in June, although below 1·5 Km. values in excess of 85 per cent were fairly frequent; values of 95 to 98 per cent have been reported.

TABLE VII—VALUES OF VAPOUR PRESSURE CORRESPONDING TO THE ABSOLUTE MINIMUM VALUES OF THE RELATIVE HUMIDITY AT 0700–0800 AT DIFFERENT HEIGHTS

| Height above M.S.L. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Km. | mb. | mb. | mb. | mb. | mb. | mb. | mb. | mb. | mb. | mb. | mb. | mb. |
| 5·0 | .. | .. | .. | 1·9 | .. | .. | .. | .. | .. | .. | .. | .. |
| 4·5 | .. | .. | .. | 1·9 | .. | .. | .. | 0·5 | 2·5 | .. | 1·7 | 3·3 |
| 4·0 | 1·3 | 1·1 | 1·7 | 0·2 | 1·2 | 0·6 | 0·2 | 0·5 | 2·5 | 3·1 | 1·6 | 2·7 |
| 3·5 | 1·3 | 0·5 | 1·5 | 0·3 | 1·7 | 0·1 | 0·5 | 0·6 | 0·5 | 1·9 | 1·6 | 3·3 |
| 3·0 | 0·7 | 1·1 | 0·3 | 0·4 | 0·6 | 0·5 | 0·7 | 0·6 | 0·6 | 0·1 | 1·3 | 0·3 |
| 2·5 | 0·1 | 0·9 | 0·6 | 0·2 | 0·6 | 0·1 | 1·0 | 0·2 | 2·1 | 0·5 | 1·2 | 0·9 |
| 2·0 | 1·5 | 0·7 | 0·3 | 0·3 | 1·1 | 0·8 | 0·6 | 1·1 | 3·7 | 0·8 | 2·4 | 1·7 |
| 1·5 | 2·6 | 0·5 | 0·9 | 0·3 | 1·9 | 0·5 | 1·9 | 1·5 | 3·7 | 3·2 | 5·7 | 1·5 |
| 1·0 | 5·9 | 2·0 | 1·7 | 0·5 | 2·5 | 2·9 | 6·3 | 3·7 | 4·5 | 7·1 | 4·9 | 4·4 |
| 0·5 | 5·7 | 4·1 | 6·5 | 0·5 | 2·5 | 5·5 | 5·4 | 5·6 | 8·9 | 10·0 | 10·9 | 2·7 |
| Surface | 5·3 | 6·9 | 6·1 | 3·7 | 11·6 | 12·3 | 17·9 | 16·8 | 19·0 | 8·1 | 11·8 | 1·5 |

**Early Morning Clouds in Summer.**—When low cloud develops in the early morning in summer a moist air layer always exists near the surface (Table VIII). In individual cases this feature is most pronounced while the upper limit of the moist layer is usually marked by an increase in temperature. Typical examples are those for June 15, 1924, July 14, 1924, August 16 and 25, 1924, and September 14, 1924 (Table IX).

The low clouds typical of summer mornings are either stratus or stratocumulus. They first appear at levels between 300 and 500 m., subsequently develop downwards and on occasions reach the ground. Owing to insolation these clouds eventually dissipate and seldom persist after 0900. It has been suggested elsewhere (7) that the formation of these stratus clouds is a radiation phenomenon and a consideration of the above aerological ascents suggests that the actual origin may possibly be the greater radiative power of moist air. It is generally accepted that most of the

TABLE VIII—MEAN VALUES OF THE TEMPERATURE AND RELATIVE HUMIDITY IN THE ATMOSPHERE ABOVE HELWAN, EGYPT, ON CLOUDY MORNINGS IN SUMMER IN 1924 AT ABOUT 0700

| | Height above M.S.L. in kilometres | | | | | | | | | | Number of occasions |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Surface | 0·3 | 0·5 | 1·0 | 1·5 | 2·0 | 2·5 | 3·0 | 3·5 | 4·0 | |
| | Temperature in °C. | | | | | | | | | | |
| June .. .. | 23·9 | 22·8 | 21·1 | 21·1 | 19·4 | 15·6 | 12·8 | 9·4 | 6·1 | 5·0 | 7 |
| July .. .. | 24·4 | 23·8 | 22·8 | 22·8 | 20·6 | 17·8 | 15·0 | 12·2 | 9·4 | 6·7 | 10 |
| Aug. .. .. | 25·6 | 24·7 | 22·8 | 22·2 | 21·7 | 20·0 | 17·2 | 15·0 | 11·7 | 8·9 | 14 |
| Sept. .. .. | 25·6 | 25·0 | 23·9 | 23·9 | 21·1 | 17·8 | 15·6 | 12·8 | 10·0 | 7·2 | 9 |
| | Relative humidity % | | | | | | | | | | |
| June .. .. | 76 | 73 | 61 | 40 | 37 | 35 | 30 | 30 | 22 | 27 | 7 |
| July .. .. | 79 | 77 | 69 | 44 | 37 | 37 | 40 | 41 | 41 | 47 | 10 |
| Aug. .. .. | 80 | 78 | 71 | 52 | 43 | 35 | 36 | 35 | 39 | 39 | 14 |
| Sept. .. .. | 85 | 79 | 57 | 46 | 45 | 44 | 41 | 44 | 61 | 28 | 9 |

absorption in the atmosphere is due to water vapour since the simple gases do not absorb appreciably either the short wave radiation from the sun or the long wave radiation from the surface of the earth.

A discussion (8) of measurements of the absorbing power of water vapour has led to the conclusion that a layer of air containing 0·3 mm. of precipitable water may be considered to behave like a black body. Consider two horizontal air layers the lower one moist and the upper one dry. Assume the temperature, $T$, to be the same for each layer and let $e_1$ and $e_2$ be the respective vapour pressures in millibars ($e_2 < e_1$). A column of air of unit cross section and length $139T/e$ centimetres will contain 0·3 mm. of precipitable water (8) and this will radiate heat at night as a black body. Thus the amount of heat lost per unit area per minute will be equal to

$$\frac{139T}{e_1}\,\rho\, c_p \frac{\Delta T_1}{\Delta t} \quad \text{for the moister air}$$

and

$$\frac{139T}{e_2}\,\rho\, c_p \frac{\Delta T_2}{\Delta t} \quad \text{for the drier air}$$

if $\Delta T_1/\Delta t$ and $\Delta T_2/\Delta t$ are the change in temperature per minute respectively for the moist and dry air columns. Since the change in $T$ during the night will be approximately steady the value of $\Delta T/\Delta t$ may be assumed approximately constant during the hours of darkness.

The amount of heat lost by the moist air equals the net flux of radiation across the plane separating the moist air from the dry air which may be written

$$E_{\text{moist}} - E_{\text{dry}}$$

TABLE IX—TEMPERATURE, RELATIVE HUMIDITY AND WIND* IN THE ATMOSPHERE ABOVE HELWAN, EGYPT, ON OCCASIONS WHEN LOW CLOUD DEVELOPED IN THE SUMMER.

| Height above M.S.L. | June 15th, 1924 | | | | July 14th, 1924 | | | | August 16th, 1924 | | | | August 25th, 1924 | | | | September 14th, 1924 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Temp. | R.H. | Wind | | Temp. | R.H. | Wind | | Temp. | R.H. | Wind | | Temp. | R.H. | Wind | | Temp. | R.H. | Wind | |
| Km. | °C. | % | ° | Km./hr. | °C. | % | ° | Km./hr. | °C. | % | ° | Km./hr. | °C. | % | ° | Km./hr. | °C. | % | ° | Km./hr. |
| 4·0 | .. | .. | .. | .. | 5·0 | 62 | .. | .. | 8·3 | 26 | 360 | 11 | 5·6 | 72 | .. | .. | .. | .. | .. | .. |
| 3·5 | 6·1 | 22 | .. | .. | 8·3 | 46 | 320 | 15 | 11·1 | 25 | 340 | 12 | 9·4 | 72 | .. | .. | 10·6 | 52 | 250 | 10 |
| 3·0 | 10·0 | 19 | .. | .. | 12·2 | 35 | 340 | 32 | 13·9 | 27 | 360 | 11 | 13·9 | 66 | .. | .. | 13·3 | 53 | 170 | 18 |
| 2·5 | 12·8 | 25 | .. | .. | 16·7 | 30 | 350 | 23 | 16·1 | 25 | 360 | 24 | 17·8 | 58 | .. | .. | 16·1 | 59 | 160 | 11 |
| 2·0 | 15·6 | 39 | 350 | 51 | 21·7 | 25 | 340 | 26 | 17·2 | 45 | 40 | 13 | 22·8 | 49 | .. | .. | 17·8 | 68 | 100 | 8 |
| 1·5 | 18·3 | 39 | 350 | 40 | 26·7 | 19 | 350 | 28 | 21·7 | 41 | 30 | 13 | 22·2 | 54 | 50 | 38 | 22·2 | 55 | 50 | 32 |
| 1·0 | 19·4 | 46 | 340 | 35 | 30·0 | 27 | 30 | 42 | 25·6 | 36 | 360 | 19 | 26·1 | 42 | 40 | 29 | 26·7 | 40 | 40 | 29 |
| 0·5 | 18·9 | 92 | 350 | 9 | 29·4 | 24 | 50 | 21 | 21·7 | 73 | 60 | 8 | 28·9 | 34 | 40 | 29 | 27·8 | 32 | 360 | 32 |
| 0·3 | 20·5 | 89 | .. | .. | 23·6 | 90 | .. | .. | 21·7 | 95 | .. | .. | 28·3 | 34 | .. | .. | 21·5 | 95 | .. | .. |
| Surface | 22·8 | 85 | 320 | 2 | 25·0 | 78 | 360 | 19 | 24·4 | 81 | 300 | 8 | 21·1 | 97 | 320 | 17 | 22·8 | 95 | 300 | 18 |

| | Weather | Weather | Weather | Weather | Weather |
|---|---|---|---|---|---|
| Heliopolis .. | 9 tenths St. at 1,500 ft. by 0300. Increased to 10 tenths and at 0700 7 tenths St. and Stcu. at 750 ft. Some Cu. persisted during morning. | Cloudless at 0300. Cloud developed to 8–10 tenths and at 0700 8 tenths St. and Stcu. at 2,000 ft. | 9 tenths Stcu. at 1,000 ft. by 0315. Increased to 10 tenths and at 0700 7 tenths Stcu. at 800 ft. | Cloudless at 0315. 10 tenths cloud developed later lowering to surface and at 0700 10 tenths St. at 150 ft. Cleared rapidly after 0800. | Overcast, 10 tenths St. at 1,500 ft. by 0330. Lowered to surface later and at 0700 10 tenths St. at 30 ft. |
| Abu Sueir .. | 10 tenths cloud developed during night and decreased to 2 tenths Stcu. at 4,500 ft. at 0300. Increased later to 8 tenths at 4,000 ft. at 0700. | Cloudless at 0300. Cloud developed later to 10 tenths on surface in places. 10 tenths St. at 800 ft. at 0700. | 8 tenths Stcu. at 2,000 ft. by 0315. Increased to 10 tenths and at 0700 9 tenths St. and Stcu. at 1,000 ft. | Cloudless throughout. | Cloudless at 0330. 10 tenths cloud developed later lowering to surface by 0640 10 tenths St. on surface at 0700. |

* Upper wind observations commenced about 0900. Upper air observations of temperature commenced 0700.

where $E$ is the radiation from the air layers, or

$$-\frac{\Delta E}{\Delta T}(T_{\text{dry}} - T_{\text{moist}})$$

$$= -\frac{\Delta E}{\Delta T}\left(\tfrac{1}{2}\left[\frac{\Delta T}{\Delta z}l\right]_{\text{dry}} + \tfrac{1}{2}\left[\frac{\Delta T}{\Delta z}l\right]_{\text{moist}}\right) \text{ where } l = \frac{139T}{e}$$

$$= -\frac{\Delta E}{\Delta T}\cdot\frac{\Delta T}{\Delta z}\left\{\frac{T}{e_2} + \frac{T}{e_1}\right\} 69{\cdot}5 \text{ gm. cal./min.}$$

whence

$$\frac{\Delta T}{\Delta t} = -\frac{T}{2\rho c_p}\cdot\frac{\Delta E}{\Delta T}\cdot\frac{\Delta T}{\Delta z}\left\{\frac{e_1}{e_2} + 1\right\} \text{°C./hr.}$$

Thus when a dry air layer is superimposed on a moist air layer the loss of heat per unit mass will be greater from the moist air layer than from the dry air layer. The value of $\Delta E/\Delta T$ is given by the following relation (9)

$$\frac{\Delta E}{\Delta T}\cdot 10^3 = 3{\cdot}0 + 0{\cdot}2\,(T - 270) \text{ gm. cal./min.}$$

Let the lapse rate in the moist air be equal to 0·6 of the adiabatic value, the mean temperature be 290° A. and the mean vapour pressure equal 25 mb. ; if the vapour pressure in the dry air is 5 mb. the computed value of $\Delta T/\Delta t$ is $-0{\cdot}64$°C./hr.

If the temperature and lapse rate in the dry air are the same as for the moist air $\Delta T/\Delta t$ equals $-0{\cdot}21$° C./hr.. The moist air layer thus decreases in temperature at a rate of 0·53° C./hr. relative to the dry air layer above due to the loss of heat by radiation. The effect of turbulence will be to modify this rate of decrease but the value obtained above is sufficiently large to show that radiation is likely to play the chief part in cooling the air sufficiently to promote the development of cloud. The conditions which existed before the development of cloud on June 14, 1924, are comparable with those used in the above calculation and add support to the suggested method of formation. The formation of stratus clouds over Lower Egypt during the summer is probably similar to the formation of such clouds over the Santa Clara Valley, U.S.A. (10), and may be regarded as a radiation phenomenon which occurs when a shallow layer of very moist air from the eastern Mediterranean exists below air of low humidity which is warmer in its lower layers than the moist air below. With this situation the excess of outgoing over incoming radiation is at a maximum at the upper surface of the

moist air and during the night the consequent cooling is sufficient to cool the air below its dew point. The dew point may not be reached first at the upper surface but at a lower level depending upon the vertical distribution of water vapour. When cloud formation occurs first at the upper limit of the moist air the growth of the cloud will be downward and may extend right down to the surface and give rise to fog. Two typical examples of this effect occurred on August 25 and September 14, 1924.

BIBLIOGRAPHY

1. NEWNHAM, E. V. ; *London, Met. Mag.*, **57**,1922, p. 215 and *London, met. Off., Prof. Notes*, **4**, No. 41, 1925.
2. PETERS, S. P ; *London, Geophys. Mem.*, **6**, No. 56, 1932.
3. SUTTON, L. J.; *Cairo, Phys. Dep. Pap.*, No. 10, 1923.
4. DINES, W. H.; *London, Geophys. Mem.*, **1**, No. 2, 1912, p. 24, Table III.
5. GOLD, E.; *London, Geophys. Mem.*, **1**, No. 5, 1913, p. 89, Table X.
6. DINES, L. H. G.; *London, Quart. J.R. met. Soc.*, **59**, 1933, p. 159, Table III.
7. FLOWER, W. D.; *London, Geophys. Mem.*, **8**, No. 71, 1937.
8. SIMPSON, G. C.; *London, Mem. R. met. Soc.*, **3**, No. 21, 1928.
9. BRUNT, D.; *London, Proc. roy. Soc.*, A124, 1929, p. 204.
10. BOWIE, E. H. ; *Washington, D.C., Mon. Weath. Rev.*, **61**, 1933, p. 40.

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